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Relationship Between Midstratospheric Temperatures and Tropospheric Synoptic Features[1]

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ABSTRACT—The relationship between midtropospheric synoptic features and midstratospheric temperatures in winter is investigated by examining averages of 5–10 yr of observations, monthly mean observations, and daily records. It is found that midstratospheric warm regions lie above midtropospheric troughs and subtropical ridges, while stratospheric cold regions occur above high-latitude tropospheric ridges. Thus, at high latitudes, an inverse correlation exists between 500-mb height and 10-mb temperatures; this correlation seems to be simultaneous in nature. The implications of these results are discussed with relation to the general circulation of the stratosphere, and in particular to the relative importance of hydrostatic adjustment, planetary wave propagation, and tidal energy.

1. INTRODUCTION

Much interest has been generated in the last 15 yr by the discovery of large-scale synoptic features in the midstratosphere. The 10-mb map for a typical winter day (fig. 1) shows warm ridges and cold troughs, with a 30°–40°C temperature variation along the 50° latitude circle. To explain the stratospheric synoptic features, one must explain these sharp temperature contrasts. They are not caused directly by radiative effects, which are negligible at 31 km (Murgatroyd and Goody 1958). Nor are they a result of in-situ kinetic energy production, which is small or negligible in the lower stratosphere (Jensen 1961, Oort 1964, Boville 1967, Manabe and Hunt 1968, Clark 1970) and in the middle and upper stratosphere (Brown 1964, Muench 1965, Julian and Labitzke 1965, Mahlman 1969, Miller 1970*a*).

Energy flux from the troposphere is considered the prime causative agent for stratospheric dynamics, apparently associated with vertically propagating planetary waves of wave numbers 1–4 (Sawyer 1965, Deland and Johnson 1968, Dickinson 1969, Miller 1970*b*). These waves probably result from a nonlinear transfer of energy from intermediate-size (synoptic scale) waves (Fjortoft 1953, Boville 1960, Saltzman and Teweles 1964, Murakami and Tomatsu 1965, Steinberg et al. 1971). Other long-wave producing features such as topography, adiabatic heating and cooling at the earth's surface, or internal heating and cooling in the midtroposphere seem to lack the ability to export energy into the midstratosphere (Murakami 1967).

Thus midstratospheric temperatures should be strongly related to tropospheric events. We will investigate this relationship from a synoptic point of view. The 10-mb level will be selected as representative of stratospheric temperature distributions because it is indicative of the trend if not actual amplitude of temperature variations throughout the stratosphere (Labitzke 1968) and data is readily available (Berlin Free University 1964–1970).

2. LONG-TERM OBSERVATIONS

To study the relationship between tropospheric and stratospheric patterns, we will first look at a longitudinal profile of height and temperature from 850 to 10 mb in January based on 5–10 yr of data. (Our discussion will concentrate on the winter months; in summer, the large longitudinal temperature variations are absent.) Figures 2–4 depict longitudinal profiles of height and temperature for latitude 50°N at various constant-pressure levels in the atmosphere.[3] The data was compiled from several sources and should be thought of more as a schematic representation, limiting its quantitative use; nevertheless, certain qualitative patterns are visible. The well-known temperature reversal between 300 and 100 mb is evident; the temperature troughs at 140°–170°E, 60°–90°W, and 10°–40°E become temperature ridges in the lower stratosphere. Likewise, the temperature ridges at 140°W and 20°W in the troposphere have disappeared by 100 mb. Furthermore, we can see that this process largely continues up to 10 mb, except at 60°–90°W where the lower stratosphere temperature ridge, never very strong, has disappeared by 10 mb. These facts are summarized in figure 5, the 500-mb height contours and the 100- and 10-mb temperatures are plotted for all longitudes at 50°N. Note that the North American 500-mb trough is surrounded by large-amplitude ridges, a fact not true for the other long-wave troughs.

A vertical profile of height and temperatures similar to those in figures 2–4 was constructed for 25°N (fig. 6) across Eastern North America and the Western Atlantic.

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[3] There is much year to year variability, especially at 10 mb, and 5 yr of data is certainly not enough to provide a meaningful average. This is, however, all the data that is currently available. Despite the variability of the temperature values, the locations of the warm and cold regions remain relatively constant.

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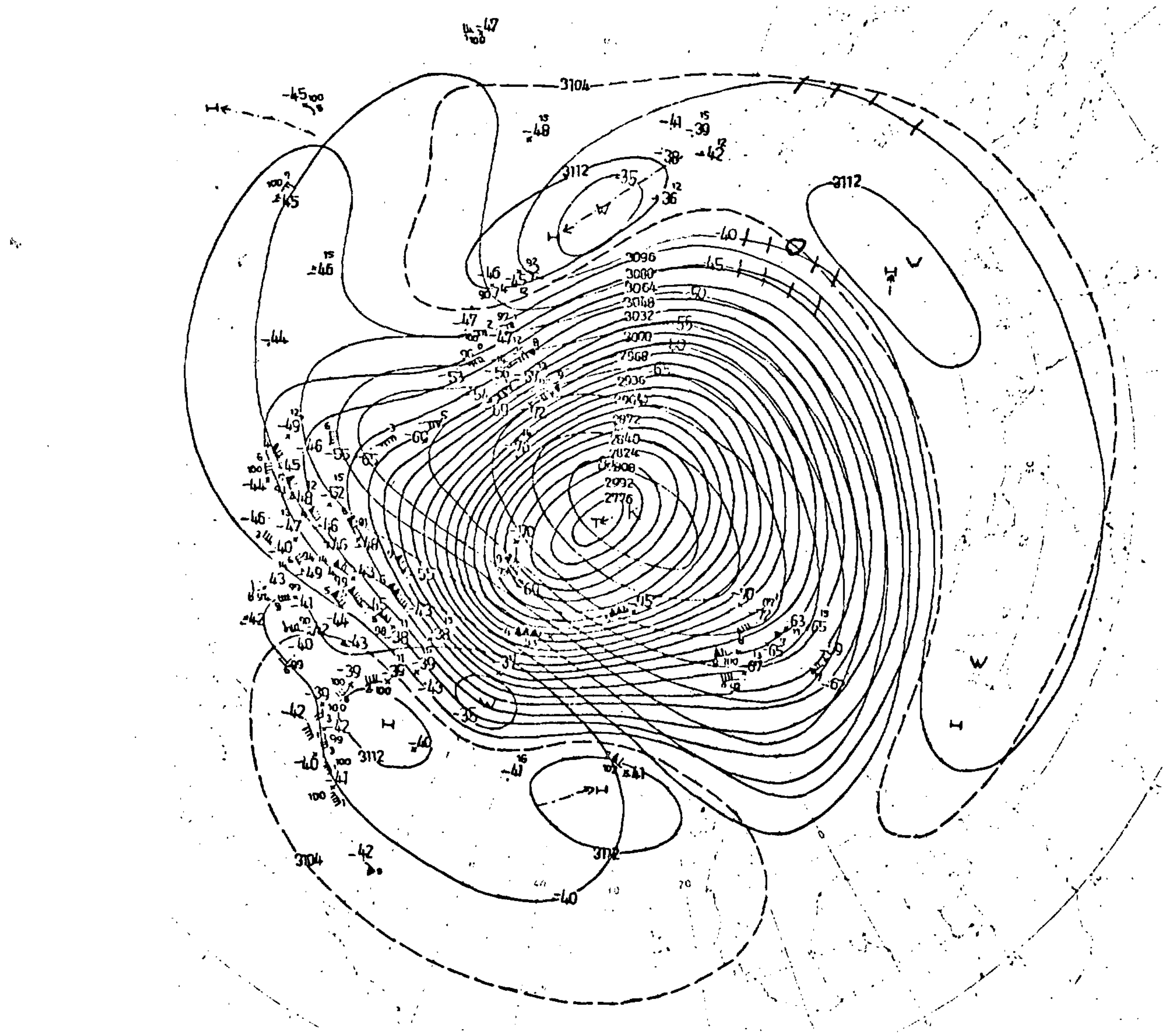

FIGURE 1.—The 10-mb stratospheric synoptic map for Jan. 1, 1964. Warm (w) and cold (k) regions are evident in the isotherm patterns, while height contours show troughs (T) and ridges (H). All 10-mb maps and data used in this study are from Berlin Free University (1964–1970).

The only feature of interest at this latitude is the subtropical High. Despite the small gradients involved, the temperature reversal between 200 and 100 mb is evident, with colder air appearing in the ridge. Another reversal takes place unexpectedly between 50 and 30 mb, as the ridge once more becomes warm. Thus, there appears to be a difference in mid-stratospheric temperature patterns above subtropical Highs and Highs at more northern latitudes.

3. MEAN MONTHLY OBSERVATIONS

We now wish to see if the patterns visible in the long-term features appear on the mean monthly maps. Mean monthly maps for 700 mb were chosen to represent the tropospheric pressure (height) contours—the patterns of interest discussed previously were already developed by 700 mb, as can be seen from figures 2–4 and 6. The 700-mb maps for the winter months of February 1966, January and February 1967, and January 1968 are shown in figures 7–10. Also shown are the corresponding mean 10-mb temperature patterns for those months. As an aid in interpretation, 700-mb Lows were given odd numbers in order of their strength (Low no. 1 was of a lower height than Low no. 3, etc.). Midlatitude and high-latitude Highs and ridges were given even numbers, also in relation to their strength (High no. 2 of greater height than High no. 4, etc.). Highs at subtropical latitudes were given letter designations in order of their strength. These alphanumeric characters were then copied onto the 10-mb maps at their 700-mb latitude and longitude. The remainder of this section provides a detailed discussion of these maps.

Looking first at February 1966 (fig. 7), we see that the major 10-mb warm area (warm areas are labeled W; cold areas are labeled K) was in close proximity to Low number 1. Even the shapes of the warm area and the Low are similar. Low number 3 was located in what appears to be an extension of the warm area eastward. The coldest region at 10 mb was directly over High number 2, and a slight extension of the cold region over the pole occurred

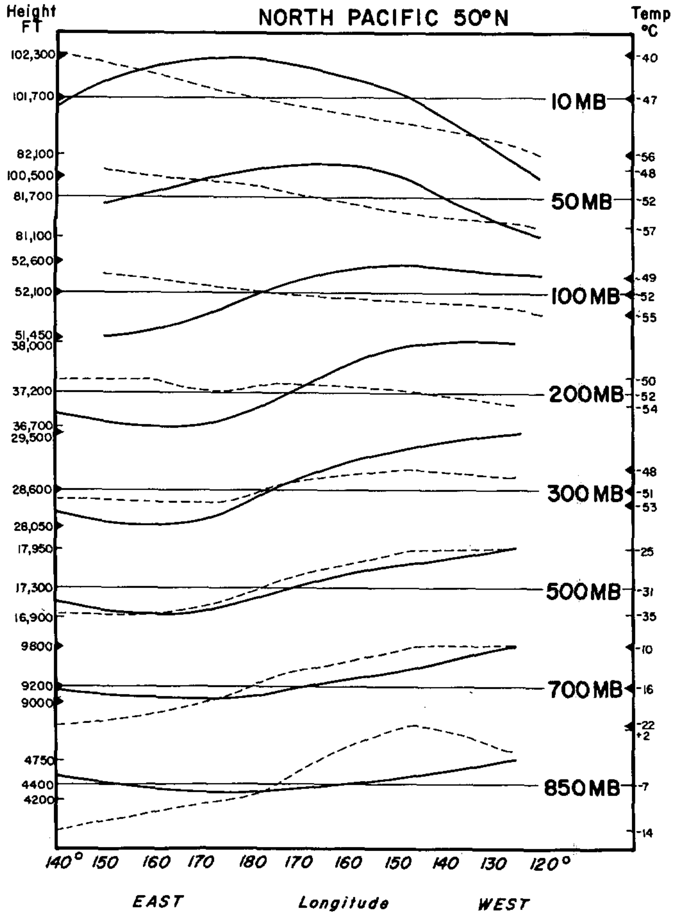

FIGURE 2.—Vertical profile of height (solid line) and temperature (dashed line) from 850 to 10 mb at 50°N across the North Pacific. [Based on tropospheric data (5–10 yr) from the U.S. Navy (1956), lower stratospheric data (5 yr) from Muench and Borden (1962), and midstratospheric data (5 yr) from Berlin Free University (1964–1970).]

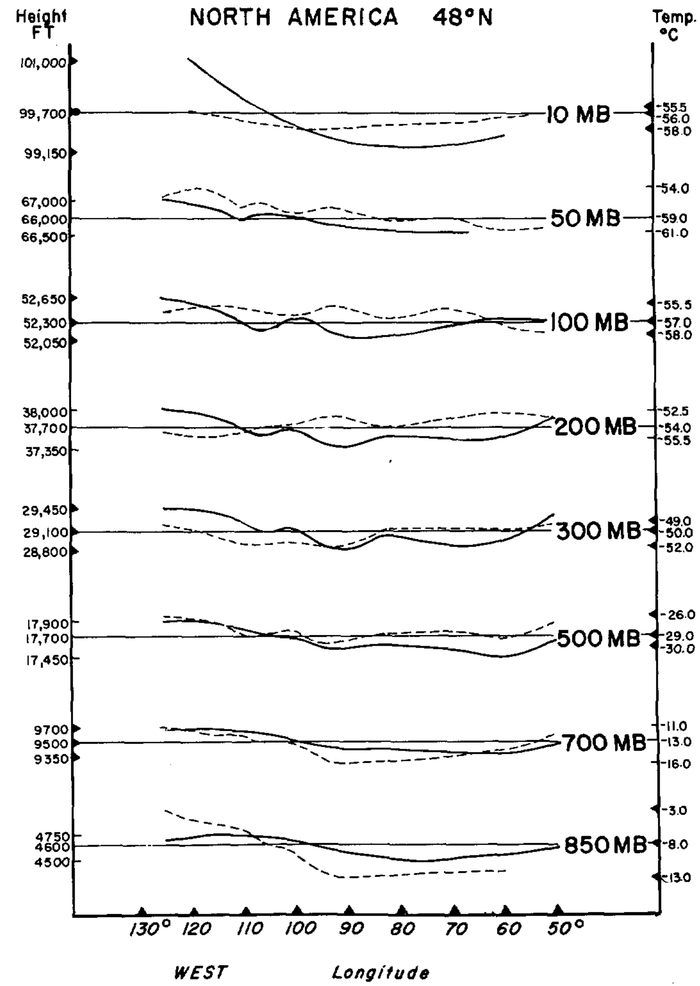

FIGURE 3.—Same as figure 2 across North America at 48°N. [Based on additional tropospheric data (10 yr) from U.S. Dept. of Commerce (1957).]

above High number 4. Low number 5 appeared on the outskirts of the cold region. We see, therefore, that at high latitudes the warm regions were generally above 700-mb Lows, and the cold regions were above 700-mb Highs. In the subtropics, Highs lettered B, C, and D appear below warm regions at 10 mb. Thus, the results for this month were identical with those observed from the long-term averages.

In January 1967 (fig. 8), the major warm region was centered over Low number 3, and extended eastward to cover Low number 7. The cold region was displaced from the pole toward High number 2. Note that all of the 700-mb Lows were on one side of the pole (Pacific side) while the 10-mb cold region was on the opposite side (European-Atlantic side). In the subtropics, Highs A, B, C, D, and E all fell within a subtropical warm region that almost circumscribed the globe.

In February 1967 (fig. 9), the strongest Lows (nos. 1, 3) are farther north than they were previously. Low number 5 lies below the somewhat weaker 10-mb Pacific warm region. The 10-mb cold center is again displaced to the side of the pole not occupied by any Low, this time occurring over High number 4.

High number 8 is not the weakest of the Highs as its number would imply—it is in fact the strongest. We deviated from the intensity numbering system described earlier in this section because of the unusual latitudinal position of the High; that is, between the high-latitude Highs and the subtropical Highs, which once more lie below 10-mb warm regions. We see that at 10 mb the cold temperature trough swings down to cover the region above High number 8, thus making it akin to the Highs farther north.

In comparing January to February 1967, we see that the strongest temperature rise (12°C) at 10 mb occurred at about 70°N, 90°W. The largest temperature falls occurred over the Pacific, reaching 7.5°C at 55°N, 140°E. Below the region of greatest temperature rise, the 700-mb Low deepened from 8,880 ft to 8,500 ft. In the Pacific below the area of largest temperature decrease, the 700-mb Low filled from approximately 8,650 ft to 8,800 ft. These changes are consistent with our understanding of the relationship of tropospheric Lows to stratospheric warm regions.

The January 1968 situation is different from the three cases just discussed. The occurrence of a stratospheric

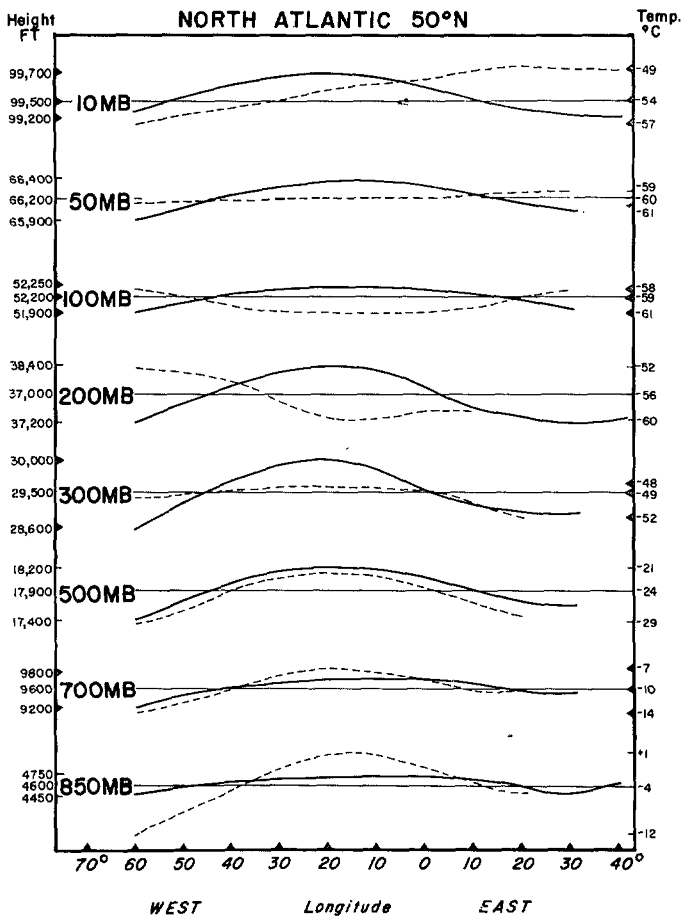

FIGURE 4.—Same as figure 2 across the North Atlantic at 50°N. [Based on tropospheric data (5–10 yr) from the U.S. Navy (1956).]

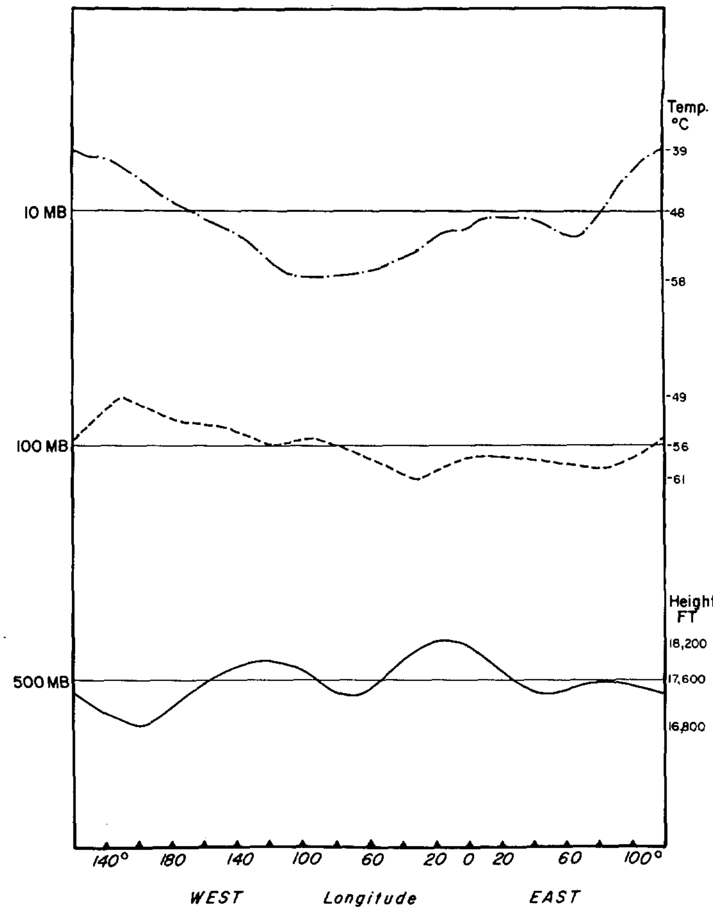

FIGURE 5.—The 500-mb height (solid line), the 100-mb temperatures (dashed line), and the 10-mb temperatures (dash-dot line) at approximately 50°N in winter. [Based on additional tropospheric data from Bolin (1950).]

warming resulted in a southward displacement of the cold polar vortex and the disappearance of the stratospheric westerly circulation. There is no guarantee that the stratosphere does not become baroclinic during stratospheric warmings, and thus become able to generate and move its warm regions independent of tropospheric events. In fact, several studies (Julian and Labitzke 1965, Mahlman 1969, Miller 1970*a*) found that baroclinic instability did occur during major stratospheric warmings. Nevertheless, it is instructive to see whether the patterns so far discerned still exist.

As can be seen from figure 10, the January 1968 mean 10-mb thermal patterns were much weaker because of the large movement of the warm and cold regions. The cold regions were displaced from the pole, which is now covered by warm air. At 700 mb, two Lows (nos. 1, 5) have completely covered the pole. In the Pacific, Low number 3 is again below a 10-mb warm region. Highs number 2 and 4 and the general ridge between Highs number 6 and 8 (again labeled such for its uniqueness) again lie below relatively cold stratospheric regions. Subtropical Highs A and C once more lie below warm regions. Thus, even for this anomalous month, the mean pattern exists; at middle and high latitudes, warm regions at 10 mb lie over midtropospheric Lows, while cold regions lie above midtropospheric Highs. In the subtropics, the warm regions at 10 mb are above the midtropospheric Highs.

4. DAILY OBSERVATIONS

The question now arises as to whether the patterns so far observed can be seen on a daily basis, or, put differently, how good an indication is the temperature at 10 mb of the pressure below, say at 500 mb, and vice versa. To investigate this, we adopted a relatively simple approach. We have seen that at middle and high latitudes the warmest 10-mb regions are above the regions of lowest tropospheric pressure. To a first approximation then, the height at 500 mb might be assumed to be inversely correlated with the temperature at 10 mb. This is to some extent a simplification of what has previously been discussed; for one thing, the magnitude of the pressure is not a true indicator of the strength of the long-wave feature. The wavelength and the pressure gradient across the feature are also indicative, and are not adequately represented by the pressure magnitude alone. Furthermore, it presumably would matter whether a given height represents a trough, ridge, or neither. These effects were partially accounted for by adopting the following procedure. The height at the center of relatively strong midtropospheric features (Lows, Highs, troughs, and ridges at 500 mb) was recorded along with the temperature at 10 mb directly above. (Features of interest were confined to those between 40° and 60°N latitude to minimize the latitudinal temperature gradient.) Choosing only strong

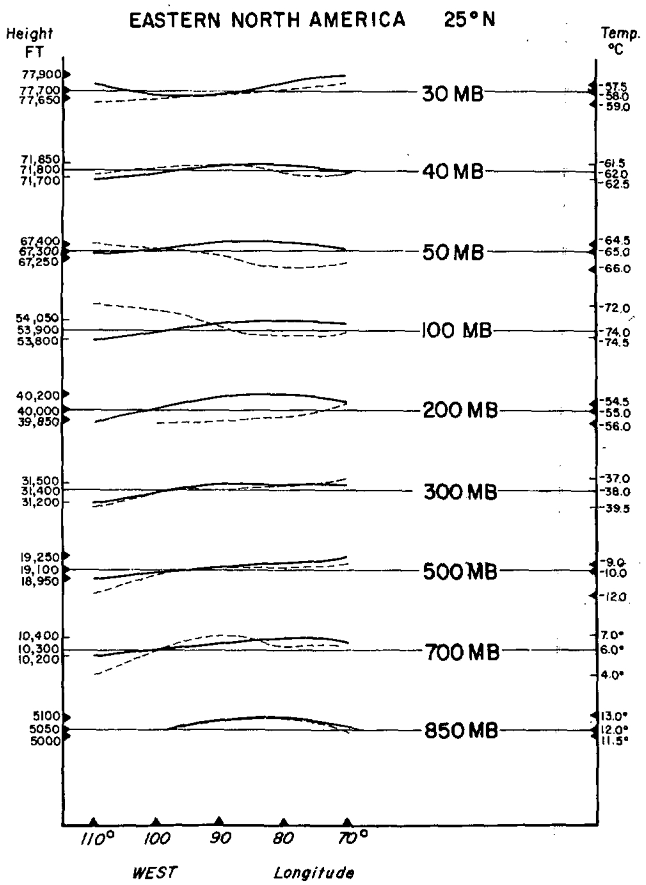

FIGURE 6.—Same as figure 2 across eastern North America at 25°N compiled from sources of figures 2–4.

features assures that the pressure magnitude is a good indication of the type of feature involved.

Thirty cases were chosen for each January for 1963, 1964, and 1966–69. For the years 1966–69, 500-mb data were available only for the Western Hemisphere. As we have seen, the strongest average effects occurred in the Eastern Hemisphere. This study, therefore, subjects the generality of the relationships previously described to their severest test.

The results of the correlation between 500-mb height and 10-mb temperature are shown in table 1. It can be seen that a correlation definitely exists with some year to year variability. As data were taken every other day, the number of independent observations should be reduced by 1/3 to account for temperature persistence. Even after this reduction, the chance that these parameters are actually uncorrelated is still less than 1 percent. In particular, we can assume the populations are normal with zero correlation and a standard deviation $\sigma=1/\sqrt{N-2}$ for large N. If the correlation coefficient exceeds 2.6σ in absolute value, the probability of its originating from uncorrelated populations is less than 1 percent (Panofsky and Brier 1958). In this case, the correlation coefficient for 180 cases is 0.4624. Reducing N by 1/3, we find $\sigma=1/\sqrt{118}=0.092$ and $2.6\sigma=0.239$. Since the correlation coefficient is well above this value, there is no doubt that 500-mb height and 10-mb temperature are (negatively) correlated. It must be noted that a correlation of 0.5

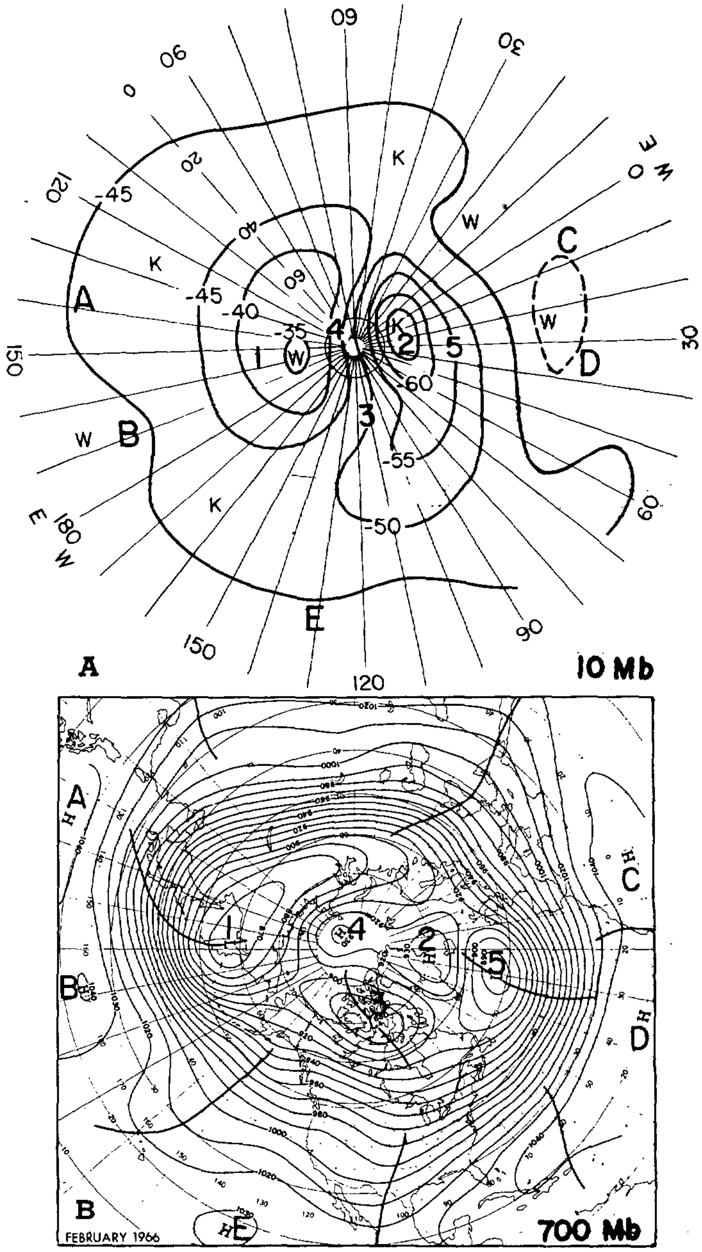

FIGURE 7.—(A) mean 10-mb isotherms and (B) 700-mb contours (Green 1966) for February 1966.

explains only 25 percent of the variance; thus, no single cause and effect relationship can be postulated. A variety of effects (i.e., different forms of vertical energy transfer, horizontal advection, etc.) may combine to produce the observed temperature patterns. Nevertheless, the association with tropospheric synoptic features has been demonstrated.

The highest correlation between 10-mb temperature and 500-mb height was found for 1968 during the stratospheric warming. Far from being independent of tropospheric events, the stratosphere would seem to be more strongly coupled to the troposphere during stratospheric warmings.

We can investigate whether or not the relationships described are simultaneous in nature in the following

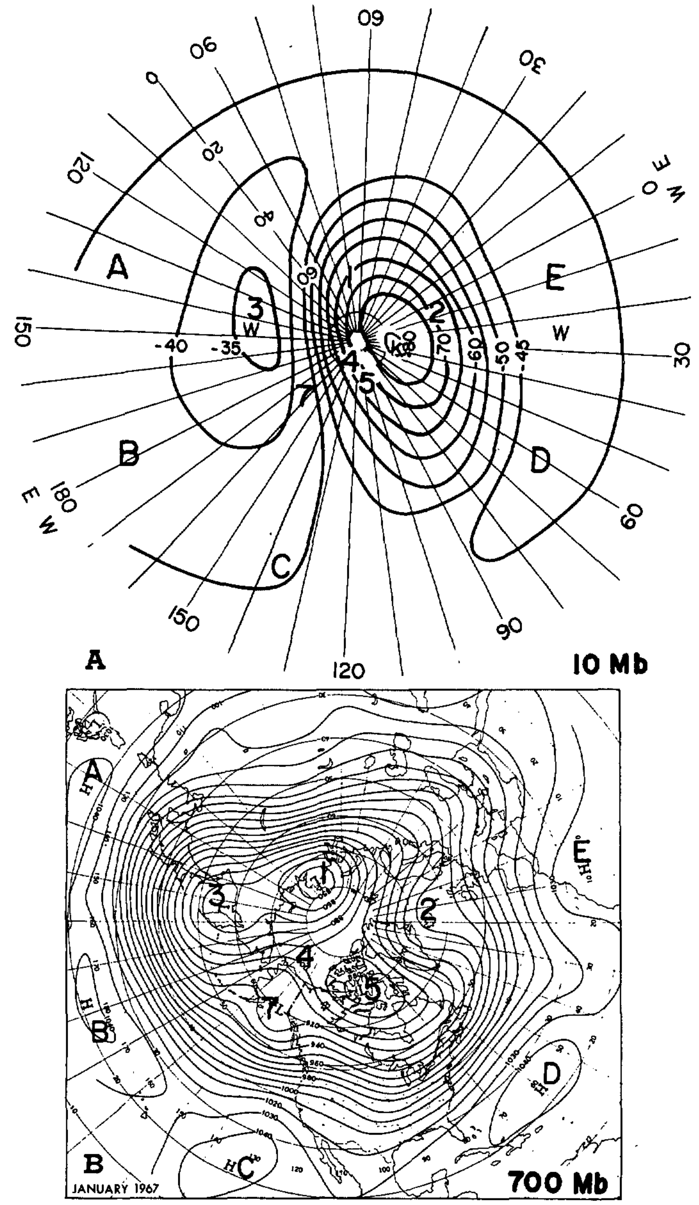

FIGURE 8.—Same as figure 7 for January 1967 [700-mb map from Winkler (1967)].

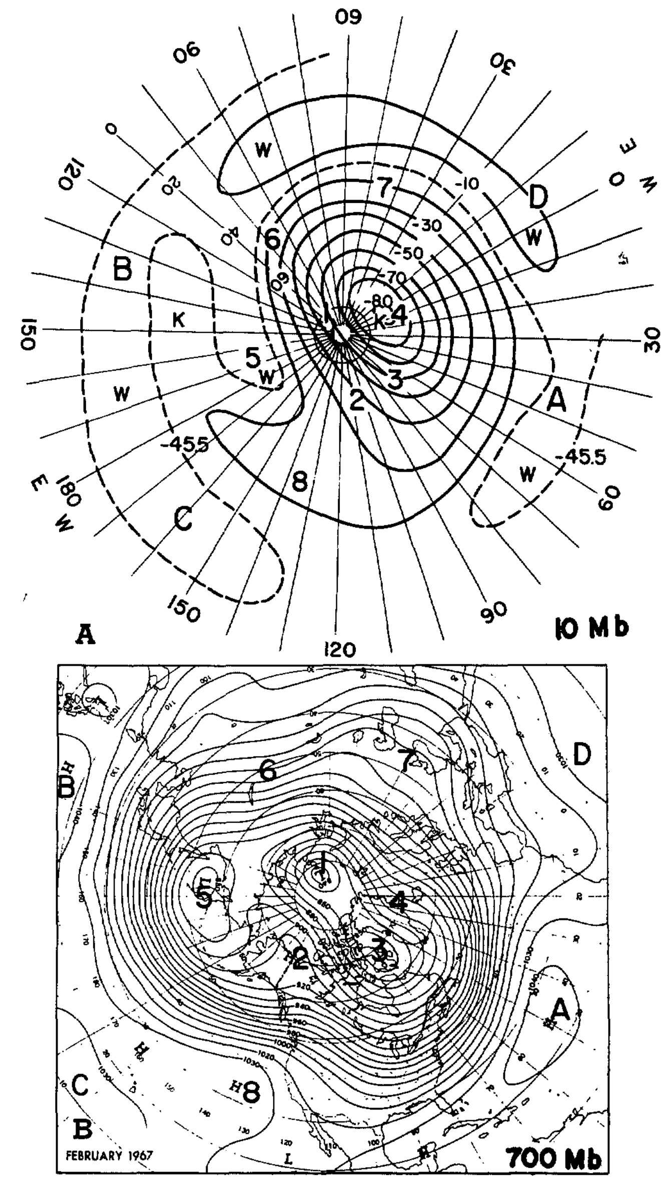

FIGURE 9.—Same as figure 7 for February 1967 [700-mb map from Posey (1967)].

TABLE 1.—*Correlation between 10-mb temperature and 500-mb height for January of various years, between 40°-60°N*

Year	No. of cases	Corr. coefficient	Data sample
1963	30	−0. 4163	Northern Hemisphere
1964	30	− . 5148	Northern Hemisphere
1966	30	− . 5145	10°W–180°W
1967	30	− . 3968	10°W–180°W
1968	30	− . 7607	10°W–180°W
1969	30	− . 4662	10°W–180°W
Total	180	− . 4624	

way. For the Western Hemisphere data, for which it was felt observations were available on a fine-enough grid to lend some meaning to the results, the 500-mb height was correlated with the 10-mb temperature of 2 and 4 days before and 2 and 4 days after.

We found that the highest correlation occurs with no lag (table 2). With this correlation as the mean and using the student t test, we found that the correlation difference between 0 days and the other days was significant at greater than the 99 percent probability level.

The straight correlation procedure was adopted to allow processing of a relatively large data sample. It is not particularly suitable for handling more subtle effects; for that reason, we can conclude only that our results *suggest* simultaneity. The importance of this result will be discussed later.

A further observational study was conducted to clarify the latitudinal variation of tropospheric-stratospheric relations. Warm regions at 10 mb were recorded for the same data sample as listed in table 1; the 500-mb long-wave feature directly below each warm region (within a 15° radius from the center of the 10-mb warm region)

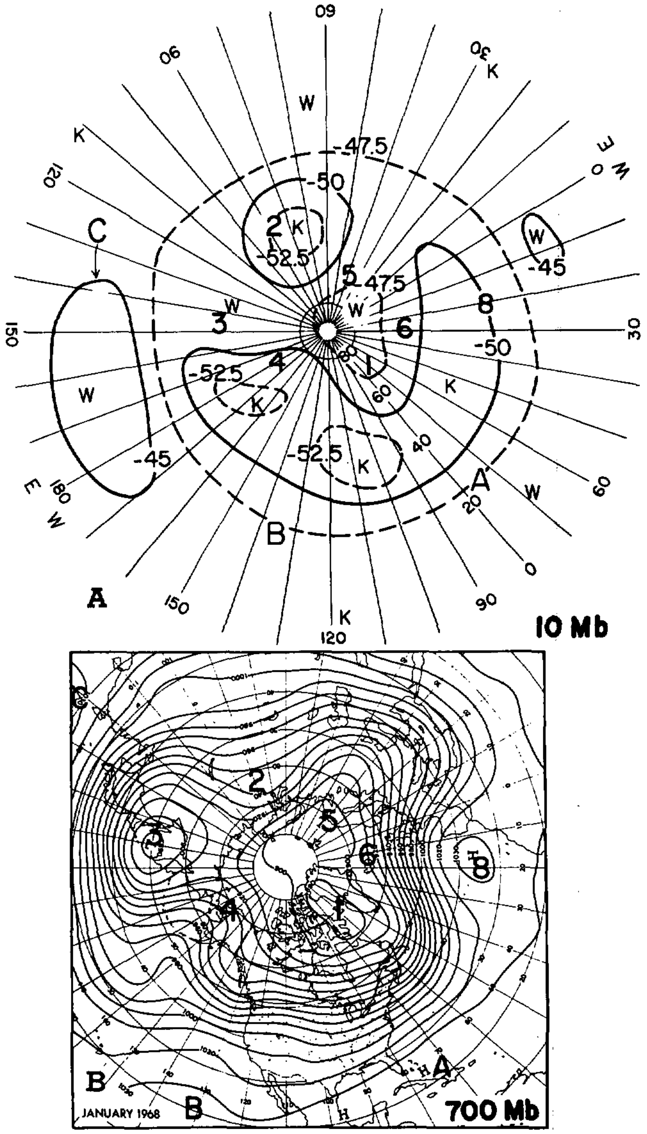

FIGURE 10.—Same as figure 7 for January 1968 [700-mb map from Wagner (1968)].

TABLE 2.—*Correlation between 500-mb height and 10-mb temperature with different lags*

10-mb temp.	−4	−2	0	+2	+4 days
Year					
1966	−0.5840*	−0.3862	−0.5145	−0.4467	−0.5423
1967	−.2392	−.2467	−.3968	−.1255	−.2245
1968	−.6786	−.6980	−.7607	−.5915	−.2871
1969	−.1628	−.3208	−.4662	−.2726	−.1566
Total	−.3694	−.3642	−.4770	−.3033	−.2179

*Smaller data sample

was also recorded. The results appear in table 3. We see that 65 percent of the 10-mb warm regions north of 40°N lie above tropospheric troughs, 71 percent of the warm areas south of 30°N are above subtropical ridges, and a "transition" region exists between 30° and 39°N.

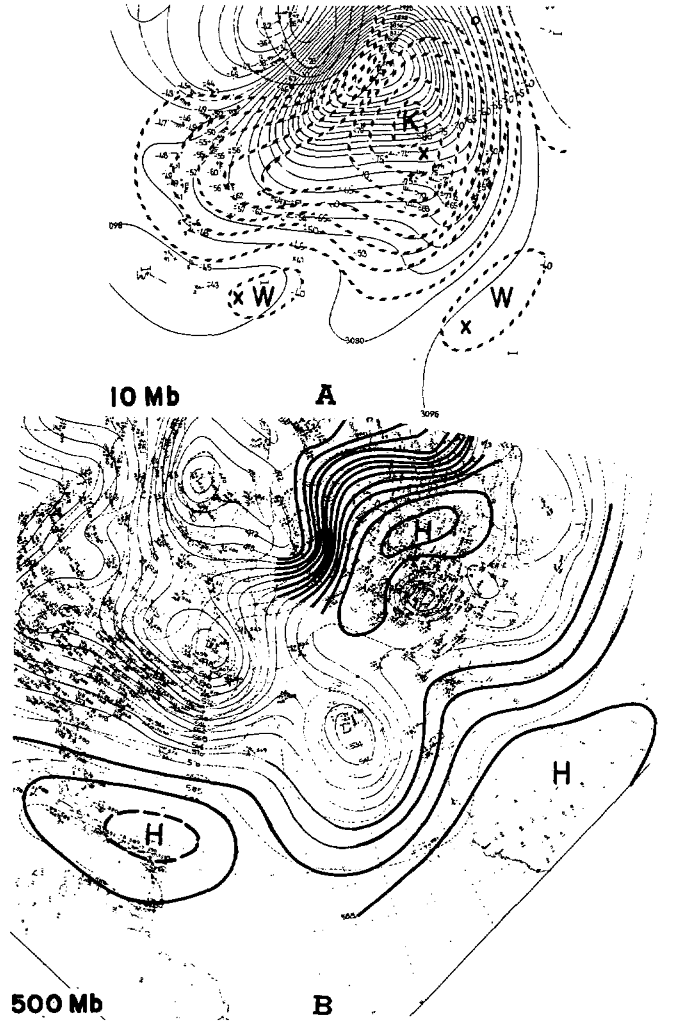

FIGURE 11.—(A) 10-mb and (B) 500-mb maps for Jan. 11, 1967. The X's on the 10-mb maps represent the centers of the 500-mb Highs.

TABLE 3.—*Distribution of 500-mb features found below 10-mb warm regions at various latitudes*

Latitude	500-mb feature		
	Trough	Ridge	Neither
40°–90°N	78	18	24
30°–39°N	12	14	9
0°–29°N	7	62	18

The results of this study are effectively summarized by the actual maps shown in figures 11 and 12. The warm regions at 10-mb are found over the 500-mb subtropical ridges and middle- and high-latitude troughs; the cold regions are found over the high-latitude ridges. The relationships appear to be of a simultaneous nature.

5. APPLICATIONS

Several immediate consequences of the relationships, which have been established on varying time scales, are apparent. By knowing the pressure variations in the mid-

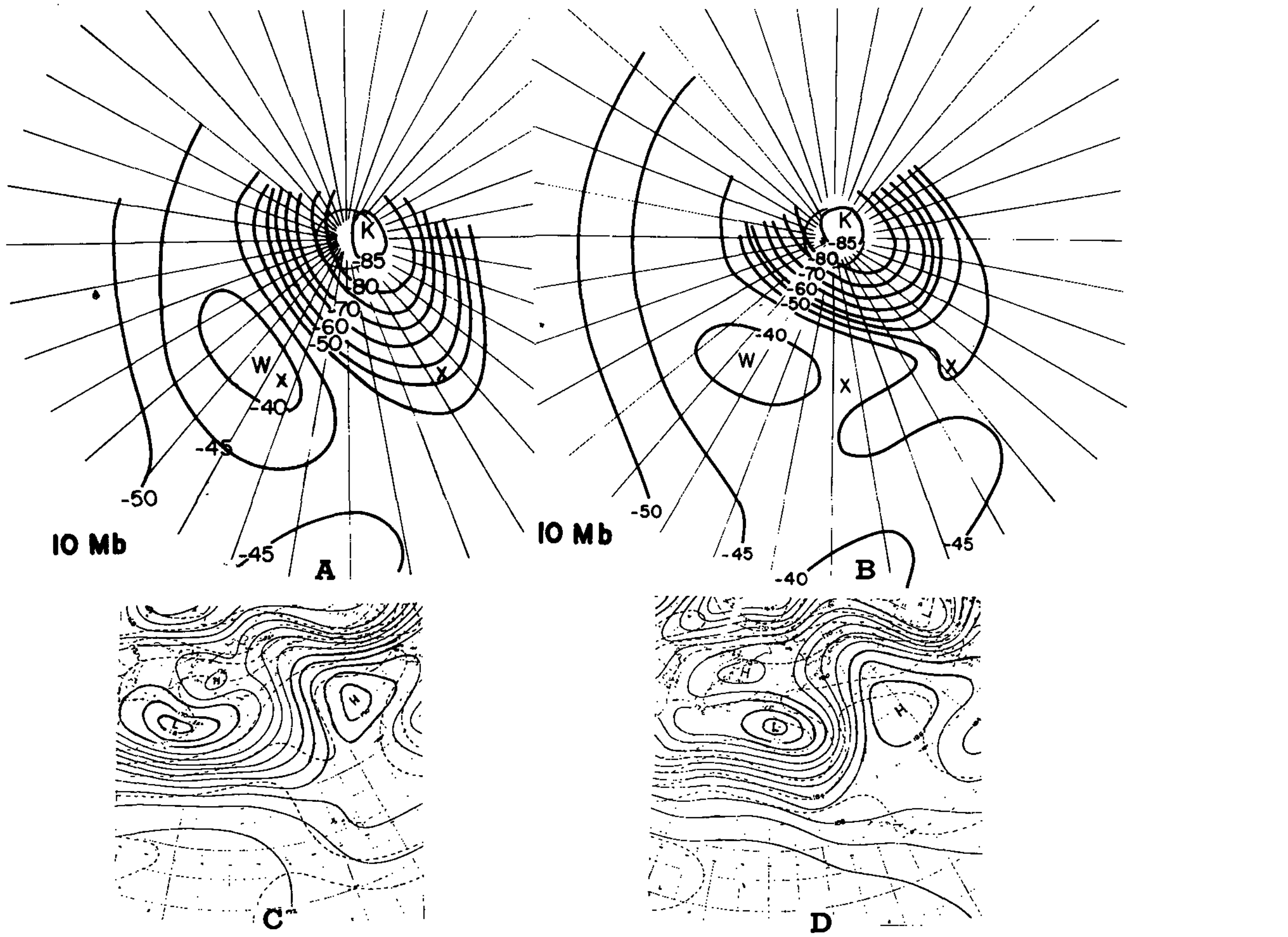

FIGURE 12.—The (A) 10-mb and (C) 500-mb maps for Jan. 9, 1963, and the (B) 10-mb and (D) 500-mb maps for Jan. 10, 1963. The X's at 10-mb represent positions of the 500-mb Low and High respectively.

troposphere, one knows, at least in a gross manner, the temperature relationships (and thus circulation) of the stratosphere and probably mesosphere as well. The importance of this obviously depends upon how exact one must be in specifying upper level parameters. For work in upper level acoustics, where only general relationships are needed, this relationship is useful.

Midstratospheric temperatures appear to be obtainable from radiation data (Belmont et al. 1968). One may speculate, therefore, that tropospheric pressure relationships are also obtainable from such data, at least in a gross way. To test this hypothesis, we reproduced figure 4 from Belmont's paper (fig. 13). Plotted are the 15-μm temperatures for Jan. 27, 1964, and the radiosonde 10-mb temperatures. We have added the 500-mb heights for the same day. From our previous analyses, we would expect the lowest 500-mb height to coincide with the highest 15-μm temperatures, and the highest 500-mb heights with the lowest 15-μm temperatures. As can be seen, this is the case; furthermore, the large pressure drop eastward across 20°E coincides with the sharp 15-μm temperature rise. This relationship is not perfect—some of the smaller scale features are missing—but it gives an idea of the inherent possibilities.

6. DISCUSSION

This technique might be useful in the Southern Hemisphere, where radiational data is more abundant than upper level pressure soundings. The Southern Hemisphere stratospheric polar vortex appears to be stronger than that of the Northern Hemisphere, with weaker longitudinal temperature gradients at 60°S (Shen et al. 1968). This is consistent with the observation that tropospheric long waves in the Southern Hemisphere are of smaller amplitude. These findings make us confident that the relationships noted between tropospheric and stratospheric features are valid for both hemispheres.

Our study has verified the initial assumption that stratospheric temperature patterns are associated with tropospheric synoptic features. The results, though, need further explanation. Why, at northern latitudes, are the warm stratospheric regions above tropospheric Lows and cold stratospheric regions above tropospheric Highs, while at low latitudes, the warm stratospheric regions are above tropospheric Highs? Furthermore, why does the relationship seem to be simultaneous in nature?

We will first discuss the low-latitude effect. The existence of stratospheric subtropical high-pressure regions

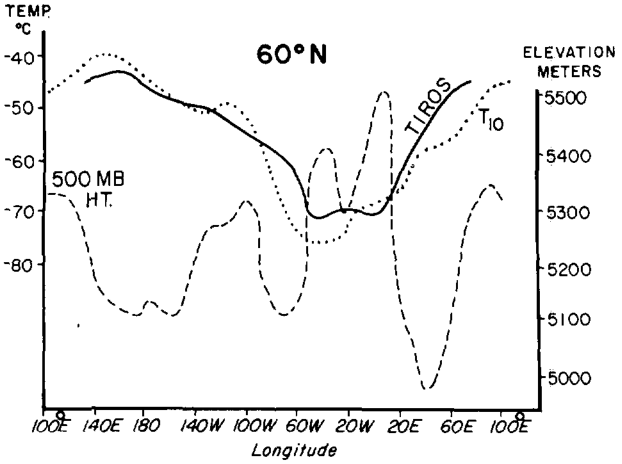

FIGURE 13.—Longitudinal profile of 10-mb temperature (dotted line) and Tiros 15-μm temperatures (solid line) at 60°N for Jan. 27, 1964 (Belmont et al. 1968). Superimposed are the 500-mb height contours for the same day.

indicates that the mass of air above these regions is greater than it is elsewhere. This may be accomplished by relative convergence of cold, denser air at higher levels in the stratosphere or above. The fact that these Highs are warm suggests that this cold, dense air has warmed by subsidence. This type of circulation fits the requirements of the expected meridional motion in the subtropics. Computations by Newell et al. (1970) indicate that cold air convergence occurs at 20°–30°N latitude as a combined result of a direct meridional cell bringing cold ascending air from the Equator and a reverse cell bringing air from higher latitudes. This air then subsides and warms.

If this interpretation is correct, the subtropical warm areas on 10-mb maps represent the effects of this circulation. The Highs would then be in a position to advect ozone and heat northward, as is required in this region.

The cold core observed in figure 6 between 200 and 50 mb may be the result of advection of the colder air located over the Tropics at these altitudes associated with the high tropical tropopause. At lower levels in the troposphere, advection once more brings in warm air, which aids subsidence in providing the observed warm core.

Thus, the subtropical Highs may be the most visible effect of the meridional circulation at these altitudes. The complex temperature-height structure would then represent the changing influences of subsidence versus advection.

What about conditions at mddle and high latitudes? It is certainly no surprise that warm, less-dense regions occur above tropospheric Lows, with cold, denser regions above tropospheric Highs. This would be expected for a basically hydrostatic atmosphere. However, to explain the stratospheric features as resulting from tropospheric processes becomes more complicated. The instantaneous nature of the tropospheric-stratospheric relationship found in this study is in contrast with those studies that have found wave and kinetic energy propagation taking several days to reach the midstratosphere from the upper troposphere (e.g., Miller 1970*b*) but is in accord with studies that found no lag between the two regions [e.g., Boville (1960) found strong cyclonic development in the troposphere and warming and subsidence at 100 and 25 mb]. We will present three possible explanations, emphasizing the instantaneous nature of the adjustments implied by our study.

1. *Vertical Energy Exchange Through Hydrostatic Adjustment.* This explanation (Johnson 1970) results from the tendency of the atmosphere to maintain hydrostatic balance and, thus, keep the ratio of potential to internal energy within a column of air constant. The internal energy change associated with lateral pressure work equals the product of gravitational potential energy and momentum divergence. Low-level troposphere convergence increases the internal energy in the lower atmosphere; therefore, the gravitational potential energy of the air column increases. The available potential energy in the stratosphere may be increased, depending on the tropopause height variation. This may lead to warming in the stratosphere. Since the hydrostatic adjustment is practically instantaneous, no significant time lag should be noted for tropospheric-stratospheric coupling. It must be noted that regions of divergence and convergence occur in the same air column throughout the troposphere. We are thus speaking of a net weighted effect leading to warming above tropospheric Lows.

2. *Planetary Wave Propagation.* Associated with a long-wave trough, planetary wave energy (in the form of a flux of geopotential associated with the perturbation vertical velocity) can propagate into the lower stratosphere, warming the absorbing region. In addition, south of 60°N, the trough in the lower stratosphere can advect warm air from the north. Once the trough becomes warm, the warm ridge immediately above in the middle and upper stratosphere would be a result of the hydrostatic effect; that is, warm regions become strong warm Highs with increase in elevation. Note that energy associated with planetary wave propagation cannot be the sole cause for stratospheric temperature distributions. It would take several days for the energy to reach the midstratosphere (Perry 1967), and our results show the lowest correlation occurs at +2 and +4 days.[4]

3. *Tidal Wave Energy.* Long waves in the troposphere provide for a longitudinal gradient of water vapor. Since maximum ozone is found in the three centers located directly above long-wave tropospheric troughs (London 1962, London et al. 1963), the long waves also in effect provide for a longitudinal gradient of ozone.

Insolation absorption by ozone and water vapor is considered to be the source for the thermal excitation of atmospheric tides (Chapman and Lindzen 1970). The action of tropospheric long waves could, thus, result

[4] It was brought to our attention in review that the flux of geopotential may be more related to the zonal available to eddy available potential energy transfer than to the eddy kinetic energy. This, in turn, may be indicative of a lag of the 10-mb height field to the temperature field.

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in varying intensities of the tidal wind, leading to relative divergence and convergence in the mesosphere and lower ionosphere. In regions of convergence, subsidence and warming could be expected; the vertical motions would be especially effective in causing warming in the stratosphere where already warmer air would be subsiding. Convergence of cold air above stratospheric warm regions by some aspect of the circulation is suggested by the recent observations of Labitzke (1972). In fact, this convergence could be the reason that, conversely, ozone is concentrated in the relatively warm air above tropospheric troughs, a dynamic rather than photochemical effect since warmth inhibits ozone production. Tidal wave energy would not propagate instantaneously, but it would take only 12 hr to reach the midstratosphere from water vapor excitation in the upper troposphere (Lindzen 1967). Observations of tidal winds in these regions are not on a fine-enough scale at this time to verify possible intensity variations.

7. CONCLUSIONS

The aim of this study was to clarify the relationship between tropospheric synoptic features and stratospheric temperatures to gain a clearer conception of the cause of the large stratospheric temperature gradients. The results show that, in general, stratospheric warm Highs are located above tropospheric Lows and subtropical Highs, with the cold troughs above upper latitude tropospheric Highs. An inverse correlation therefore exists at high latitudes between midstratospheric temperatures and midtropospheric pressures at the center of midtropospheric features. This correlation is highest during a major stratospheric warming, emphasizing, perhaps, the strong coupling between the troposphere and stratosphere during this phenomenon. It implies further that radiation observations from satellites, apparently capable of indicating 10-mb temperatures, may thus also provide an indication of gross longitudinal pressure variations especially important in the Southern Hemisphere.

The results also suggest that the relationship between two levels is instantaneous. Recent results (Deland and Friedman 1972) indicate no lag in events between the stratosphere and ionosphere, although several days lag was expected. These studies may thus emphasize the importance of hydrostatic adjustments throughout a large vertical extent of the atmosphere, and/or possibly the heretofore uninvestigated importance of tidal wave energy in indirectly determining the temperature field of the stratosphere.

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